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# Investigating the Rheological Characterization of Rice Bran Oil Biodiesel

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## Abstract

**Biodiesel is an increasingly attractive alternative to diesel fuel. The main component of rice bran oil biodiesel (RBOB) is methyl palmitate (C16:0), which is a saturated fatty acid with a high melting point. Controlling flow properties, such as viscosity and the cold filter plugging point, is critical because viscosity affects atomization, and crystal formation resulting from decreases in temperature can negatively affect engine starting and performance. To evaluate its flow characteristics more fully, the rheological properties of RBOB were analyzed AR-G2 rheometers, taking into account variations in temperature. The results showed that the rheological properties of RBOB are affected by temperature and shear rate. The viscosity of RBOB rose sharply when closed to the cold filter plugging point (CFPP), leading to the RBOB viscosity-temperature curves having an inflection point that was coincident with both the transition from a Newtonian-type flow to a pseudoplastic-type flow. Above the temperature of the CFPP, RBOB showed the characteristics of plastic fluid.**

## Keywords

**Biodiesel, Rheological, Rice bran oil, Fatty acid esters.**

## 1. Introduction

The viscosity of biodiesel limits its large-scale application, because viscosity affects fuel atomization in the injection chamber during the combustion process, damaging the system. Higher-viscosity fuels have an increased tendency to cause such problems [1].

Biodiesel viscosity depends on properties such as temperature and chemical structure. [2-3] The dependence of viscosity on temperature has been analyzed for biodiesels obtained from cottonseed oil [3]. Ester crystal nuclei that are visible to the naked eye form at low temperatures. As the temperature decreases, crystal growth and agglomeration continue until the crystals are large enough to restrict the free flow of fuel in the pipes and filters.

Rheology techniques have been used to investigate the correlation between the chemical structure and the physical properties of biodiesel [4-5]. Fatty acid esters with different chain lengths and degrees of unsaturation were used to evaluate the influence of chemical structure on rheology and crystallization temperature. Although esters displayed Newtonian behavior at room temperature, pseudoplastic behavior was observed at temperatures closed to CFPP. Microcrystal formation at low temperatures may be responsible for this high viscosity, which can cause serious problems in the engine fuel lines and filters.

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In this study, the rheological properties of biodiesel obtained from rice bran oil were analyzed as a function of temperature. The results were correlated with the behavior observed using AR-G2 rheometers.

## 2. Experimental

### 2.1. Materials and Equipment

Rice bran oil biodiesel is prepared using transesterification process in which triglyceride portion of the oil reacts with methanol and NaOH to form ester and glycerol. All other chemicals were purchased from Aladdin Reagent Co., Ltd. (Shanghai).

AR-G2 rheometer: TA Instruments; Trace MS gas chromatography mass spectrometer: the Finnegan; SYP2007-1 petroleum products cold filter plugging point tester: Shanghai Boil Equipment Limited Company.

### 2.2. Analytical

The chemical compositions were analyzed by GC-MS. Cold filter plugging point (CFPP, °C) and kinematic viscosity (KV, 40°C, mm2·s−1) were determined according to SH/T 0248-2006 and GB/T 265-1988, respectively. Rheological characterization was determined by AR-G2 rheometer.

## 3. Results and discussion

### 3.1. Rice Bran Oil Biodiesel Composition, Cold Filter Plugging Point and Kinematic Viscosity

According to GC-MS analysis, the result is shown in Table 1.CFPP and KV values of RBOB were -2 °C and 7.16 mm2·s−1, respectively. Clearly RBOB exists problems such as high kinematic viscosity, poor low temperature fluidity, which greatly limits the application of RBOB.

**Table 1.** GC-MS analysis of rice bran oil biodiesel

| RBOB | $C_{14:0}$ | $C_{16:0}$ | $C_{18:0}$ | $C_{20:0}$ | $C_{22:0}$ | $C_{16:1}$ | $C_{18:1}$ | $C_{20:1}$ | $C_{22:1}$ | $C_{18:2}$ | $C_{18:3}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (w)% | 0.36 | 16.37 | 2.20 | 0.73 | 0.29 | 0.30 | 42.74 | 0.64 | 0.49 | 34.19 | 1.39 |

$C_{m:n}$ : m means the number of fatty acid carbon atoms; n means the double-bond number in fatty acid group.

### 3.2. Interfering Factor of Kinematic Viscosity

(1) Temperature

The apparent viscosity of RBOB under different temperature was determined by AR-G2 rheometer, and the viscosity-temperature curve was shown in Fig. 1.

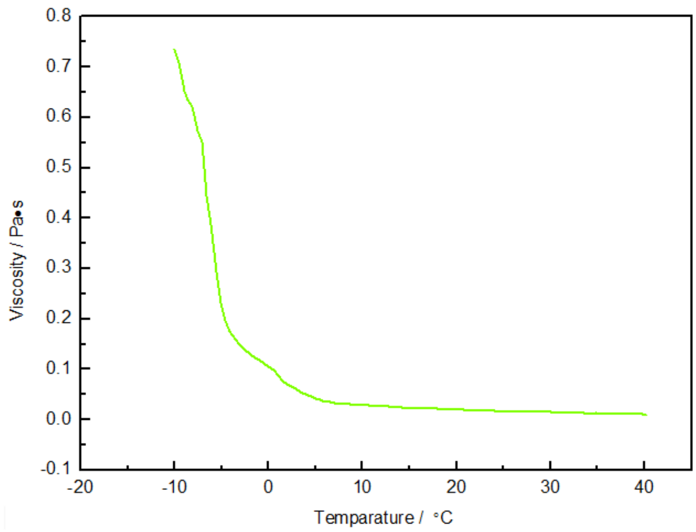


**Fig 1.** Viscosity-temperature curve of rice bran oil biodiesel.

It can be seen from the Fig. 1 that the viscosity-temperature characteristics curve can be divided into two sections and an inflection point. Before the inflection point, the curve is flat. After turning point, the curve becomes very steep. The reason is that the temperature of RBOB decreases to its CFPP, resulting in a sharp increase in viscosity. So low temperature rheological property of RBOB is poorer. The temperatures of the inflection points is- 1°C; while the corresponding CFPP are - 2°C. It indicates that the inflection point is close to CFPP but higher than CFPP. Low temperature crystallization causes viscosity of RBOB suddenly rise and RBOB flow from the Newton fluid into non -Newton fluid.

(2) Shear rate

The viscosity-shear rate curves of RBOB under different temperature was shown in Fig. 2.

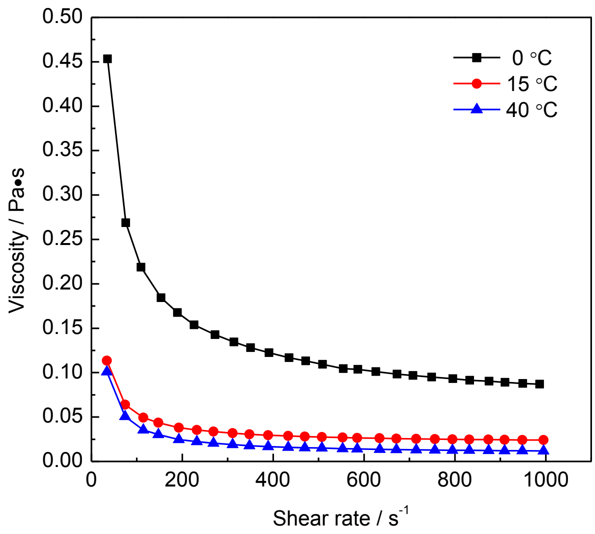


**Fig 2.** Viscosity-shear rate curve of rice bran oil biodiesel.

It can be seen from the Fig. 2 that at the shear rate of about 200 (1/s), the viscosity-shear rate curves have a sharp decrease. When the shear rate is less than 200 (1/s), the viscosity-shear rate curves are steep. While the shear rate is more than 200 (1/s), the viscosity-shear rate curve is flatter and the viscosity remains almost unchanged. The results show that at low shear rate RBOB behave as the non-Newton fluid characteristics, while at high shear rate showing Newton fluid characteristics. RBOB has shear thinning phenomenon, and high temperature is more obvious than low temperature.

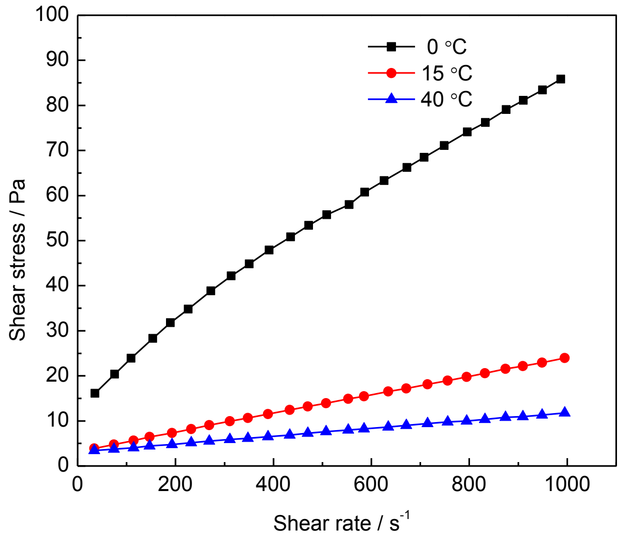


**Fig 3.** Liquid Curves of rice bran oil biodiesel.

(3) Flow curve and Bingham model

The flow curve of RBOB under different temperature was shown in Fig. 3. As shown in Fig. 3, above the CFPP shear stress is proportional to shear rate; and the lower the temperature, the steeper the flow curve. These results suggest that above the CFPP, RBOB flow show plastic fluid or Bingham fluid characteristic.

The flow curve fitting of RBOB based on the Bingham model under different temperature has been done in this paper. And the fitting equations and various parameters was shown in Table 2. Above the CFPP, the fitting correlation coefficient (r2) of RBOB is larger than 0.99. The results illustrate that the Bingham model can better characterize the rheological properties of RBOB. The plastic consistency coefficient (ηp) of RBOB decreases with the temperature increasing, namely viscosity of RBOB decreases with temperature increasing. The yield force (τ0) of RBOB was around $3P_a$.

**Table 2.** Bingham model of RBOB

| $t$ /°C | Bingham equation | $\tau_0$ /Pa | $\eta_p$ /Pa·s | $r^2$ |
|---|---|---|---|---|
| 0 | $\tau$ =18.08+0.071$\gamma$ | 18.08 | 0.071 | 0.9930 |
| 15 | $\tau$ =3.36+0.021$\gamma$ | 3.36 | 0.021 | 0.9998 |
| 40 | $\tau$ =3.15+0.009$\gamma$ | 3.15 | 0.009 | 0.9996 |

## 4. Conclusion

(1) The viscosity of RBOB decreases with temperature increasing and rises sharply when close to CFPP, leading to the viscosity-temperature characteristics curve having an inflection point. And the inflection point is close to but higher than the CFPP.

(2) RBOB shows characteristics of non-Newton fluid at low shear rate along with the shear thinning phenomenon while showing characteristics of Newton fluid at high shear rate, and the shear thinning phenomenon at high temperature is more significant than low temperature.

(3) Above the temperature of the CFPP, RBOB shows the characteristics of plastic fluid, which can be better described by the Bingham model.

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